PROTOCOL TO DEVELOP ALBERTA WATER QUALITY GUIDELINES FOR PROTECTION OF FRESHWATER AQUATIC LIFE

Environmental Assessment Division
Environmental Regulatory Service

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This protocol represents the Department's approach to developing Alberta guidelines for the protection of aquatic life. This protocol is based on sound scientific principles, which result in protective guidelines. Similar procedures are used in several other jurisdictions. In order to develop Alberta guidelines for the protection of aquatic life, this document is considered to be a final document. However, we recognize the value of comments from the public and stakeholders. Therefore, comments from the public are invited until September 30, 1997.

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EXECUTIVE SUMMARY

This protocol describes how Alberta Environmental Protection develops water quality guidelines for the protection of aquatic life. The purpose of these water quality guidelines is to protect aquatic life against unacceptable toxic effects.

This protocol develops guidelines that:

- provide a consistent, high level of protection;
- consist of acute and chronic values;
- are based on high quality, scientific information for many different organisms;
- can be either full, interim, or site-specific;
- consider factors to adjust and apply them.

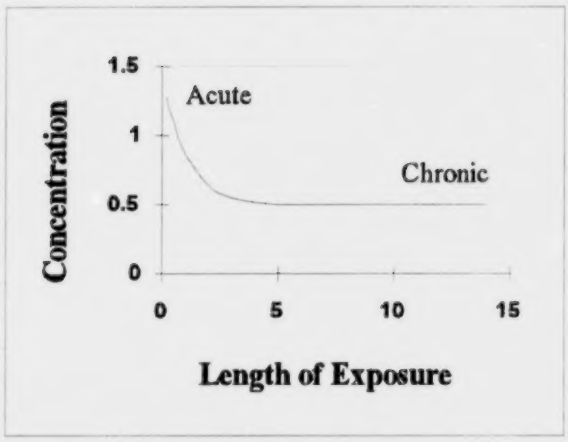
Consistent, High Level of Protection

The general philosophy of water quality guidelines for protection of aquatic life is to protect all components of the aquatic environment. However, it is not practical or feasible to determine the effects on all forms of aquatic life and all aspects of aquatic life cycles for each water quality parameter. The available scientific information is therefore extrapolated to a guideline value that is expected to provide a high level of protection. Various protocols used in other jurisdictions were reviewed and evaluated to determine the best approach.

Based on an extensive evaluation, the approach used by the United States Environmental Protection Agency (USEPA 1985) was chosen as the basis for developing Alberta guidelines for the protection of aquatic life. Other approaches either did not provide a consistent, high level of protection or resulted in considerable overprotection. This protocol uses statistical concepts to translate the general philosophy of protecting aquatic life into guidelines that provide a consistent, high level of protection to aquatic life.

Acute and Chronic Guideline Values

The intent of guidelines developed with this protocol is to protect aquatic life against unacceptable toxic effects. Toxicity depends on the length and magnitude of exposure, as illustrated in the following figure:



Exposure to high concentrations over short periods can result in mortality (acute effects). Exposure to low concentrations over longer periods can affect growth, reproduction or survival (chronic effects). Acute guidelines are developed to protect aquatic life against short-term exposure to high levels of a contaminant. Chronic guidelines are developed to protect against long-term, low level exposure. To protect aquatic life from a wide range of toxic effects, Alberta guidelines consist of both acute and chronic values.

Acute and chronic guidelines allow Alberta Environmental Protection to assess and prevent acute and chronic toxicity, respectively. Previously, only chronic guidelines were available in Alberta. When water quality did not meet these chronic guidelines, the presence of acute toxicity could not be determined. The presence or absence of both acute and chronic toxicity can be determined by comparing water quality monitoring information to the new Alberta guidelines developed with this protocol. Acute and chronic guidelines further allow management of water quality below effluent discharges. Alberta guidelines developed with this protocol will be used to protect aquatic life and prevent unacceptable acute and chronic toxic effects. The interpretation and application of the new Alberta guidelines is fully integrated with the setting of water quality based effluent limits as outlined in "Water Quality Based Effluent Limits - Procedures Manual" (AEP 1995). This integrated approach allows Alberta Environmental Protection to protect and manage water quality in a coherent manner.

High Quality, Scientific Information for Many Different Organisms

Guidelines are derived with a large quantity of information obtained from the scientific literature. Toxicity information is classified based on laboratory techniques. Only high quality information is used in deriving guidelines. Furthermore, information on a minimum

of eight different animal species from eight different families is required for development of a full guideline. Additional information on plants is required for chronic guidelines. These species represent a large variety of taxonomic and functional groups in the aquatic environment (different species of fish, invertebrates and plants). Previous guidelines used in Alberta required fewer toxicity data points from less diverse species. The new Alberta guidelines are therefore more reliable than previous guidelines.

Full, Interim and Site-specific Guidelines

Full Alberta guidelines are derived with toxicological data from a large number of appropriate taxa and functional groups. The number of taxa and their variety are representative of freshwater aquatic communities in Alberta.

If insufficient information is available for a full guideline, interim guidelines can be developed. An interim guideline derived as a full guideline may not provide sufficient protection for aquatic life. Uncertainty factors are therefore used to address data deficiencies and provide additional protection. These uncertainty factors are based on the data available and the characteristics of a compound.

When full Alberta guidelines are applied to a specific site, they may in some cases be under- or overprotective. Aquatic species at a site may be more or less sensitive than those used to develop the provincial guideline. The physical and/or chemical characteristics of water at a site may alter the biological availability and/or toxicity of a compound. In these situations, the provincial guideline may be adjusted to develop a site-specific guideline.

Considerations to Adjust and Apply Guidelines

General guidance is provided on how to adjust, apply and interpret the guidelines derived with this protocol. Guidelines can be adjusted to be consistent with other environmental criteria. Proper application of specific guidelines requires additional information about potentially unacceptable indirect effects. Natural conditions and atypical situations may affect the application of specific guidelines. General guidance is provided on the acceptable frequency, duration and magnitude of exceeding a guideline. Guidance is also provided on how to deal with mixtures of toxic materials in surface water.

1. INTRODUCTION

1.1 Context for developing Alberta Guidelines

AEPEA

The purpose of the Alberta Environmental Protection and Enhancement Act (AEPEA) is to support and promote the protection, enhancement, and wise use of the environment. To further the protection and wise use of the environment, the Alberta Environmental Protection and Enhancement Act (AEPEA) provides for the development of guidelines and ambient environmental quality objectives for all or part of Alberta (Section 14, AEPEA). Guidelines are numerical concentrations or narrative statements recommended to support and maintain a designated water use. Development of Alberta water quality guidelines was initiated in 1970 (Surface Water Quality Criteria Province of Alberta), updated in 1977 (Alberta Surface Water Quality Objectives) and 1993 (Ambient Surface Water Quality Interim Guidelines).

Definition

1993 Guidelines

These (1993) interim guidelines are applicable to surface waters except sometimes in areas of close proximity to outfalls. The designated uses considered for these guidelines were raw water supply for treated drinking water, propagation of fish and other aquatic life, contact- and non-contact recreational activities, and agriculture.

1.2 Purpose of the New Alberta Water Quality Guidelines

Aquatic Life

This protocol outlines the procedures to develop Alberta water quality guidelines for the protection of aquatic life (Alberta guidelines). These guidelines do not address protection for other uses (e.g., agriculture, human health).

Toxic

The new Alberta guidelines are based on the toxicological information gathered during a comprehensive review of the literature. With this protocol, guidelines are therefore developed for those water quality parameters that are toxic to aquatic life. Water quality guidelines may also protect water uses other than aquatic life: e.g., recreation, aesthetics (e.g., phosphorus, colour, plant biomass). Different approaches will be developed to derive guidelines for these other water uses.

Water Exposure

The scientific literature is reviewed for those studies, in which aquatic organisms are exposed to water and various conditions of a particular water quality parameter (e.g., concentrations of a specific chemical or a physical condition like

water temperature). Only results from high quality studies are used in deriving a guideline. Application of these guidelines will therefore protect aquatic life from effects of water exposure. Exposure of aquatic life to some chemicals through uptake from sediments or bioaccumulation through food consumption can be significant. In these situations, exposure from all major routes (water, sediment and food consumption) should be evaluated together in order to protect the entire aquatic ecosystem.

Acute-chronic

This document provides the framework to develop compound-specific water quality guidelines for the protection of aquatic life. This framework is a departure from previous Alberta water quality guidelines. The new approach results in a two-level guideline (acute and chronic) as opposed to the previous one-level (chronic) guideline. A two-level guideline was adopted for two reasons: (1) acute and chronic guidelines better capture the toxic effect of magnitude and duration of exposure on aquatic life than a single chronic guideline, and (2) chronic guidelines alone do not allow an assessment and/or prevention of unacceptable acute effects in surface water. This document also provides advice on how guidelines should be used, where they can be applied and how they can be modified for site-specific applications.

Review

These new guidelines will replace the 1993 interim guidelines as they become available. Water quality parameters for guideline development will be selected based on stakeholder consultation and government priorities. The new guidelines will be initially reviewed by Alberta Environmental Protection. After this internal review, the new guidelines will be reviewed with key stakeholder participation, such as the general public, general interest groups, scientific community, municipalities and industry.

1.3 Transition to the New Alberta Guidelines for the Protection of Aquatic Life

Guidelines are used as screening levels for evaluation of monitoring data and for setting approval limits for effluent discharges. Currently a variety of guidelines are used for these purposes. Until a set of new Alberta water quality guidelines is available, Table 1 outlines the recommended sequence for using various water quality guidelines.

This sequence supersedes the sequence recommended in the Water Quality Based Effluent Limits Procedures Manual for acute and chronic guidelines (AEP 1995). The

USEPA guidelines are preferred over Canadian Water Quality Guidelines (CWQG) because the philosophy behind the new Alberta guidelines and the USEPA guidelines is similar. Both Alberta and USEPA guidelines provide a consistent, high level of protection. The level of protection of CWQG varies with the available information. The use of CWQG and United States Environmental Protection Agency (USEPA) guidelines is therefore reversed in the recommended sequence. The new sequence does not affect the use of USEPA Gold Book values (USEPA 1986) for human health guidelines recommended in the Water Quality Based Effluent Limits Procedures Manual (AEP 1995).

Table 1. Recommended Sequence for Using Existing Guidelines.

Acute Guidelines	1. New acute guidelines for the protection of aquatic life developed with this protocol.
	2. If a new guideline has not been developed with this protocol, use the most recent United States Environmental Protection Agency (USEPA) acute guideline.
Chronic Guidelines	1. New chronic guidelines for the protection of aquatic life developed with this protocol.
	2. If a new guideline has not been developed with this protocol, use 1993 Alberta Ambient Surface Water Quality Interim guidelines. These guidelines should be treated as chronic guidelines.
	3. If 1993 Alberta Ambient Surface Water Quality Interim guidelines do not exist, use the most recent USEPA chronic guidelines.
	4. If there are no USEPA chronic guidelines, use the Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CWQG) as chronic guidelines.

2. IMPORTANT FEATURES OF THE NEW ALBERTA GUIDELINES

This chapter describes in general terms the characteristics of Alberta water quality guidelines for the protection of aquatic life (Alberta guidelines).

2.1 Guideline Designation: Full, Interim or Site-Specific

This protocol contains procedures to develop full, interim and site-specific guidelines.

Full

Protection of aquatic life depends on the use of a reliable guideline. Reliability of a guideline for a specific water quality parameter depends to some degree on the available information. A reliable guideline requires information on the fate and effect of a specific water quality parameter in the environment and quantitative information on exposure-effect relationships. Full guidelines can be derived when sufficient information is available for a reliable guideline (Chapter 3).

Interim

In some instances, it may be necessary to develop a guideline without all the necessary scientific information (lack of sufficient toxicological information on all necessary species, or lack of environmental fate information). In these instances, interim guidelines may be developed (see Chapter 4). The procedures result in acute and chronic interim guidelines that provide a high level of environmental protection.

Site-specific

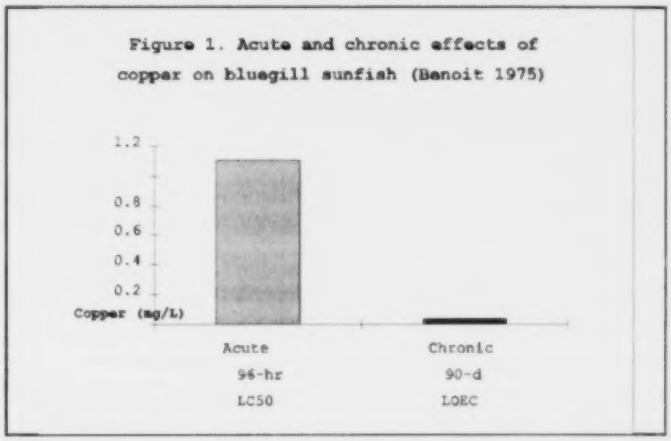
Full guidelines will be applicable to most surface water in Alberta. In a few instances, these full guidelines may not apply to some bodies of water: sensitive species may or may not be present at a site, forms of the chemical are not toxic at a site, or natural conditions at a site do not meet guidelines. This protocol includes procedures to adjust full provincial guidelines to site-specific conditions (Chapter 5). These site-specific procedures contain the general approach to develop guidelines that protect aquatic life at a site. Some of the details will depend on the specific characteristics of the site. Carrying out studies needed to develop site-specific guidelines will generally be the responsibility of stakeholders. However, extensive consultation with Alberta Environmental Protection will be required to: determine the need for developing site-specific guidelines, ensure that proper procedures are followed, and ultimately develop a guideline that is protective of aquatic life at the site.

2.2 Alberta Guidelines: Acute and Chronic Values

The procedures for deriving freshwater aquatic life guidelines in this protocol result in two numbers: acute and chronic. The two-number approach is chosen because it reflects more accurately the toxicological and practical realities:

Toxicological

The toxic effects of a water quality parameter on aquatic biota depend on magnitude and duration of exposure to the compound. Exposure to higher levels or over longer time periods is more toxic than lower levels or over shorter periods, respectively. Therefore, measurements of acute toxicity (e.g., mortality over 96 hours) and chronic toxicity (e.g., growth, reproduction or survival over much longer periods) are made. For example, Figure 1 indicates the acute effect level of copper in a short-term exposure (96-hr LC_{50} [concentration lethal to 50% of the organisms in 96 hours]) and chronic effect level in a long term exposure (LOEC [lowest observed effects concentration] 90-day survival; data from Benoit 1975). This figure illustrates the interaction of magnitude and duration of exposure on the effects to fish: high concentrations of a toxicant can only be tolerated for short time periods whereas low concentrations can be tolerated for longer time periods.

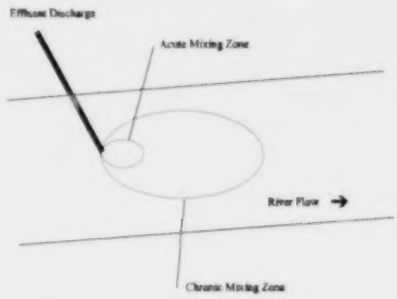


Practical

Acute and chronic guidelines allow Alberta Environmental Protection to evaluate surface water: including surface water affected by effluent discharges, spills, surface runoff and other unusual conditions. Chronic toxicity is generally a more sensitive measure of effects compared to acute toxicity; chronic toxicity is expressed at lower levels and over longer time compared to acute toxicity. To adequately assess and manage water quality and protect aquatic life, a one-number guideline would therefore have to be a chronic guideline. Chronic guidelines however are not always met in point source effluents, spills and other unusual conditions. Figure 2 illustrates an effluent, that does not meet an acute guideline, discharged into a river. Acute toxicity occurs in a small acute mixing zone, and chronic toxicity occurs in a chronic mixing zone. A chronic guideline can be used to assess the extent of the chronic mixing zone. However, it cannot be used to evaluate acute toxicity below effluent discharges or in effluents. Similarly, acute toxicity from other sources (e.g., spills, tributary streams or non-point sources like surface

runoff) cannot be adequately assessed without an acute guideline. Furthermore, acute toxicity cannot be restricted below an effluent discharge without an acute guideline. The use of acute and chronic guidelines in limiting effluent discharges (approval limits) is described in the Water Quality Based Limits Procedures Manual (AEP 1995). That manual outlines the stringent and reasonable assumptions on averaging period, frequency of exceedance, flow and effluent loads. These assumptions are used with acute and chronic guidelines to set actual water quality based licence limits that limit acute and chronic toxicity in areas affected by effluent discharges.

Figure 2. Illustration of a mixing zone below an effluent discharge



Acute and chronic guidelines reflect the expression of toxicity with respect to the magnitude and duration of exposure. In addition, use of acute and chronic guidelines allows the assessment and management of toxicity in all surface waters, even if they are affected by point sources or non-point sources.

2.3 Derivation of a Guideline Value

The general philosophy of water quality guidelines for freshwater aquatic life is to protect all components of the aquatic environment. However, it is not practical or feasible to determine the effects on all forms of aquatic life and all aspects of aquatic life cycles for each guideline. The available information is therefore extrapolated to a guideline value that provides a high level of protection.

Various protocols used in other jurisdictions were reviewed and evaluated. The method used by the United States Environmental Protection Agency (USEPA 1985) was chosen as the basis for developing Alberta guidelines for the protection of aquatic life. The rationale for this choice was that the USEPA method results in guidelines that provide a consistent, high level of protection to aquatic life.

The detailed steps to derive guideline values may appear to be complex; they are based on statistical concepts. Alberta guidelines are derived with toxicological data from a minimum of eight different functional (e.g., grazers, predators) and taxonomic (e.g.,

salmonid, non-salmonid bony fish) groups. Chronic guidelines also require toxicological data for plants. The number of groups and their variety are representative of freshwater communities in Alberta. The procedures have the following characteristics:

- take into account all available information,
- focus on the most sensitive groups,
- use statistical concepts to reduce bias, skewness, and variability,
- provide an objective way to extrapolate and interpolate data,
- allow additional protection based on expert judgement and review, and
- result in accurate guidelines that have only a small possibility of considerable over- or underprotection.

These procedures result in guidelines that provide a high level of protection and prevent unacceptable long-term and short-term effects on aquatic life in Alberta.

2.4 Uncertainty Factors

Full Alberta guidelines are derived with toxicological data from a substantial number of different functional and taxonomic groups, representative of freshwater communities in Alberta. The guideline value is set to prevent short-term and long-term toxic effects on aquatic species. The specific calculations result in guidelines that provide a reasonable and high level of protection with only a small possibility of overprotection or underprotection (USEPA 1985). Based on expert judgement further adjustments may be required. A final guideline is adjusted to ensure protection: (1) of sensitive ecologically, commercially or recreationally important species, and (2) against other biologically important effects (such as bioaccumulation) that may negatively affect aquatic biota. Full guidelines are therefore protective and do not require additional uncertainty factors.

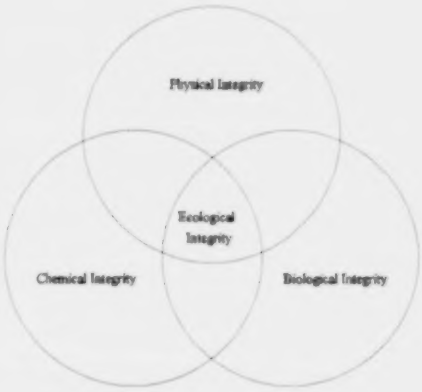
Interim guidelines are developed without all the necessary scientific information for a full guideline. Deriving an interim guideline in a similar way as a full guideline may not be sufficiently protective for freshwater aquatic life. Uncertainty factors are therefore used to provide additional protection to address the data deficiency. The value of an uncertainty factor depends on the quantity and quality of the available data.

Additional information is used to adjust full guidelines for a site. These site-specific guidelines provide the same level of protection at a site as the Alberta guidelines provide for Alberta surface water. Similar to full guidelines, site-specific guidelines require no additional uncertainty factors.

2.5 Ecological Integrity

Ecological integrity is only possible when chemical, physical and biological integrity is achieved (USEPA 1990, Figure 3). The water quality guidelines derived with this protocol protect aquatic life from toxic conditions whether they are specific chemicals or physical conditions (such as water temperature) in water. This protocol therefore addresses chemical integrity and to some degree physical integrity.

Figure 3. The elements of ecological integrity.



Biological integrity is functionally defined as:
the condition of the aquatic community inhabiting the unimpaired waterbodies of a specified habitat as measured by community structure and function (USEPA 1990).
A variety of biological criteria can be used to describe the biological integrity or level of impairment of aquatic communities. These biological criteria require direct measurements of resident aquatic biota. For example, they can be numeric values or narrative expressions that identify impairment from sediment contamination, habitat alteration, bioaccumulation in tissues. These biological criteria can be used to protect benthic organisms (organisms living in or on bottom sediments) or rooted aquatic plants from exposure to sediments. In addition, biological criteria can take into account accumulation of toxicants in fish tissue or in consumers of aquatic biota (wildlife and human health).

The application of water quality guidelines developed with this protocol will result in chemical and to some degree physical integrity. The need for specific biological criteria (such as sediment guidelines or tissue residue guidelines) will be identified in the documents for each water quality guideline developed with this protocol.

2.6 Expert Judgement

This document provides specific procedures on how to develop full, interim and site-specific guidelines. However, set procedures may not be totally appropriate for all compounds or all data sets. Some flexibility is maintained in this document to make

adjustments to the procedures to ensure that guidelines are indeed protective. The appropriate places for adjustment based on expert judgement are specified in the procedures. Adjustments for deriving a guideline for a particular compound however need to be clearly documented in the guideline report for that compound. A rationale for the adjustment also needs to be provided.

2.7 Revision

The guidelines derived with this protocol will be based on the best scientific information presently available. Review and revision of these guidelines may be undertaken when warranted by new information.

2.8 Application/Use of Guidelines

It is important to understand the limitations in using the guidelines and how these guidelines are intended to be applied.

Surface water quality is affected by natural conditions, point source and non-point source discharges of compounds, and flow conditions. In reality, water quality may not always meet all guidelines. Under natural conditions, aquatic biota are naturally subjected to a series of stresses. The effects on aquatic biota depend not only on the magnitude of these stresses but also on their duration (Section 2.2). When water quality slightly exceeds acute or chronic guidelines, it usually results in little or no ecological effects and requires little or no time to recover. Therefore, acceptable duration of an exceedance (averaging period) and acceptable frequency of exceedance concepts are adopted. These are further explained in Chapter 6.

Chapter 2 provides some guidance on application and interpretation. Additional guidance on application and interpretation of these guidelines is provided in Chapter 6.

3. PROCEDURES TO DERIVE FULL WATER QUALITY GUIDELINES FOR PROTECTION OF AQUATIC LIFE

Existing protocols to develop water quality guidelines for protection of aquatic life were reviewed. Two main approaches (CCME 1991 and USEPA 1985) are currently in use. The USEPA is considering a new ecosystem approach.

Ecosystem approach

The USEPA is considering a new framework for guideline development that takes an ecosystem approach. This framework integrates dose-response relationships with meaningful population- and community-level measures (C.G. Delos, USEPA. n.d. Possible Revisions to EPA's Procedure for Deriving Aquatic Life Criteria. 7p.). Alberta has **not** adopted this approach at this time for the following logistical reasons. Surface water in Alberta varies substantially in physical, chemical and biological characteristics from cold headwaters in the mountains to warmwater prairie streams at the Alberta-Saskatchewan border. Establishing meaningful population- and community-level measures may therefore be difficult. The analyses and determination of acceptable effects will be more complex with the new framework. Also, the use of population and community assemblage effects as endpoints may be less stringent than considering acute and chronic effects on individual organisms/species. However, the new framework will be evaluated once the specifics are finalized and some experience is gained with the new approach.

Existing Approaches

The two main methods currently used to derive water quality guidelines were compared (CCME 1991 and USEPA 1985). The main difference between the two methods is how the available data from several aquatic species are extrapolated to a guideline that protects aquatic life. One method uses an explicit uncertainty factor that is independent of the data available (CCME 1991). The other method uses an implicit (statistical) approach considering all available data (USEPA 1985). To evaluate the two methods, guidelines were calculated from existing toxicological data with the two methods and compared. This evaluation indicated that explicit uncertainty factor guidelines based on few data were less protective than statistically derived guidelines (based on the same data). Also explicit uncertainty factor guidelines based on many data were overprotective compared to statistically derived guidelines (based on the same data) (see Appendix 1). The implicit (statistical) method was therefore adopted as the basis for developing Alberta guidelines.

Alberta Approach

The procedures are designed to derive a full acute and chronic guideline; however, it can only be used if the minimum data requirements are met. The procedures generally

follow the USEPA protocol for water quality criteria for aquatic organisms and their uses (USEPA 1985). Some modifications are made to reflect elements of the CCME (1991) protocol and characteristics of Alberta surface water. These modifications are outlined in this chapter. Guidance on how to apply these guidelines is provided in Chapters 2 and 6.

Succinct Description

In brief, the procedures to derive guidelines for the protection of aquatic life start with an extensive literature review, proceed with classification of the toxicological information for fish, invertebrates, amphibians and plants, and calculate a final acute value, final chronic value and a final plant value. Generally, the acute guideline for Alberta will be one-half of the final acute value; the chronic guideline will be equal to the lower of the final chronic value and the final plant value. Depending on the literature review (presence of sensitive key species, cumulative toxicity, genotoxicity [ability to damage an organism's genetic material], bioaccumulation potential or other unacceptable effects of a compound), a lower value may be adopted for the final acute value and the chronic guideline. Details and rationale are provided in the remaining text of this chapter.

3.1 Literature Search and Data Classification

For each water quality parameter selected, a literature search is conducted to obtain information on:

- physical and chemical properties
- production and uses
- sources to the aquatic environment
- environmental concentrations in Alberta
- environmental fate and behaviour
- method of analysis and detection limits
- bioaccumulation potential
- acute toxicity to freshwater aquatic biota
- chronic toxicity to freshwater aquatic biota
- genotoxicity
- organoleptic (taste and odour) effects (if applicable)
- effect of compound in mixtures
- guidelines from other jurisdictions.

Data Classification

Each toxicological study found in the literature search is evaluated to ensure that good laboratory practices were used in the design and execution of the experiment. This generally implies that a primary study uses flow-through conditions

and confirms, by direct measurement, test concentrations and conditions in each experimental chamber. Each study is classified as primary, secondary or unacceptable according to CCME (1991) criteria (see Appendix 2).

Meaningful Test Results

Primary data should reflect the total adverse effect of the water quality parameter tested. Sensitive lifestages (usually early lifestages) should therefore be used in acute toxicity tests. For instance, daphnids should be less than 24 hours old. Generally, the duration of an acute test is 96 hours and the endpoint is mortality or immobility of 50% of the individuals. For chronic tests, duration depends on the test species. Tests over the entire life cycle of a species are preferred. However, results from partial life-cycle toxicity tests are acceptable for fish species that require more than a year to reach sexual maturity. Results from early life-stage toxicity tests may also be used. However, these results should be carefully scrutinized to ensure that they represent the entire life cycle. The endpoint of a chronic test is the geometric mean of the no observed effects concentration (NOEC) and the lowest observed effects concentration (LOEC).

Experimental Conditions

Any scientific finding regarding the effect of feeding on acute toxicity values or effects of unusual dilution water (high total organic carbon, particulate matter or chelators) on toxicity values should be documented and considered in classifying toxicity studies.

Non-native Species

Studies on species not present in North America should be flagged and discarded if the toxicity values are beyond the toxicity values for species resident in North America. As outlined in Sections 3.3 and 3.4, toxicity values for Alberta species can be used to adjust the guideline if the species are ecologically, commercially or recreationally important.

3.2 Required Information for a Full Freshwater Aquatic Life Guideline

The Alberta approach to develop water quality guidelines essentially follows the USEPA 1985 method. Several adjustments were made:

1. The calculation of a final residue value as outlined in USEPA (1985) is omitted in the Alberta protocol. A protocol for deriving tissue residue guidelines is currently being prepared by CCME. The tissue residue guideline would protect consumers of aquatic life from dietary exposure of contaminated aquatic biota. Instead of adopting the USEPA procedure for deriving a final residue value, the CCME protocol will be reviewed and compared to the USEPA approach. The best approach will be adopted in Alberta.

2. Use of marine or estuarine toxicological information will not be used in deriving Alberta guidelines to reflect the lack of this water in Alberta. This ensures that the information base for the Alberta protocol is the same as for the CCME protocol.

3. Based on sound expert judgement, minor alterations in the particular families required for guideline derivation are allowed. However, the minimum requirement of eight different families has to be met.

Data Requirements

After the classification of the literature information, the following information must be available to derive a full water quality guideline for the protection of freshwater aquatic life:

- Primary data from acute tests with at least one species in eight different families: Salmonidae (in the class Osteichthyes), a second family in the class Osteichthyes, a third family in the phylum Chordata (may be in the class Osteichthyes or may be an amphibian), a planktonic crustacean, a benthic crustacean, an insect, a family in a phylum other than Arthropoda or Chordata, a family in any order of insect or any phylum not already represented.
- Minor alterations in the particular families required for guideline derivation are allowed based on sound expert judgement. However, the minimum requirement of eight different families has to be met.
- Acute-to-chronic ratios with species of aquatic animals in at least three different families provided that of the three species: at least one is a fish, at least one is an invertebrate, at least one is an acutely sensitive species.
- Primary data from at least one alga or vascular plant. If plants are among the aquatic organisms that are most sensitive to the material or the material is phytotoxic, results of a test with a plant in another phylum (division) should also be available.
- All toxicological data must be for freshwater species.

The number of different families (eight) was adopted to represent a large number of appropriate taxa from an appropriate variety of taxonomic and functional groups and thus provide a reasonable and high level of protection. Reducing the number of families to less than eight would not provide a reasonable and high level of protection. Values less sensitive than the average sensitivity in the data set would be used to calculate a final acute value and thus the acute guideline (refer to Section 3.3.1 and Appendix 3).

3.3 Intermediate Steps in Calculating Alberta Guidelines

3.3.1 Calculation of a Final Acute Value (FAV)

FAV

The acute data are screened for appropriate life stages and agreement within and between species (see Appendix 3 and USEPA 1985). Species mean acute values (SMAVs) are calculated as the geometric mean of all primary data for each species (Appendix 3). The genus mean acute values (GMAV) is the geometric mean of all SMAVs within a genus. The GMAVs are ranked and the cumulative probability (P) is calculated. The four sensitive GMAVs closest to the cumulative probability (P) of 0.05 are used to calculate a final acute value (FAV). Use of the small fraction of 0.05 is chosen to prevent FAVs from being too high or too low relative to the data sets from which the FAVs were derived (Appendix 3; USEPA 1985). Further details, explanation and illustration are provided in Appendix 1 and Appendix 3. In some instances, the FAV needs to be adjusted to provide additional protection. Rationale for and advice on appropriate adjustments are outlined under "expert judgement" in this section.

Example

The calculation is illustrated below in Table 2 for chlorine in freshwater (USEPA 1984). In total, primary data are available for 28 genera (12 invertebrate and 16 fish) with a total of 33 species. The genera are ranked and the calculation is performed with the four genera closest to the cumulative probability of 0.05 (Table 2).

Table 2. **Calculation of the Final Acute Value (FAV) for Chlorine in Freshwater** (values are in µg/L, USEPA 1984). Total number of genera is 28. GMAV is genus mean acute value, P is the cumulative probability. To reduce variance, skewness and bias, natural logarithm (ln) and square root (√) transformation are used for GMAV and P, respectively. S and L are values for the slope and intercept of the relationship between the four transformed GMAV and P values closest to P=0.05. The value A is the ln-transformed toxicity value corresponding to P=0.05. For further explanation of terms and equations, see Appendix 3.

Rank	GMAV	ln(GMAV)	ln(GMAV)^2	P	√P
1	27.66	3.320	11.022	0.034	0.186
2	63	4.143	17.166	0.069	0.263
3	69.57	4.242	17.997	0.103	0.322
4	72.74	4.287	18.377	0.140	0.371
3(R1-4)		15.992	64.563	0.345	1.141
$S^2 = (64.563-(15.992)^2/4))/(0.345-(1.141)^2/4) = 32.551$ $S = \sqrt{32.551} = 5.705$ $L = (15.992-5.705*1.141)/4 = 2.370$ $A = 5.705*(\sqrt{0.05})+2.37 = 3.646$ $FAV = e^{3.646} = 38.318$					

Expert Judgement

In some cases, the species mean acute value (SMAV) for a commercially, recreationally, ecologically important, threatened or endangered species could be lower than the calculated FAV. In these situations, the SMAV for that sensitive species **should** be used as the FAV instead of the calculated FAV.

The calculated FAV could potentially be far below the toxicity endpoint of the most sensitive genus. Even if the dataset meets the requirements for a full guideline, this situation may occur when the dataset is relatively small, and the variability among the four most sensitive genera is large. This situation is illustrated in Table 3.

Table 3. Calculation of the Final Acute Value (FAV) Resulting in a Value Below the Lowest GMAV. Total number of genera is 8. For explanation of terms, see Appendix 3.

Rank	GMAV	ln(GMAV)	ln(GMAV)^2	P	%P
1	0.1	-2.30259	5.301898	0.111111	0.333333
2	0.2	-1.60944	2.59029	0.222222	0.471405
3	0.2	-1.60944	2.59029	0.333333	0.57735
4	2.7	0.993252	0.986549	0.444444	0.666667
3(R1-4)		-4.52821	11.46903	1.111111	2.048755
$S^2 = 102.6983$ $S = 10.13402$ $L = -6.32258$ $A = -4.05655$ $FAV = 0.017309$					

In these situations, the general approach (outlined in detail in Appendix 3) may be modified. Expert judgement may be used to determine if the extrapolated FAV value is unreasonable. If commercially, recreationally, ecologically important, threatened or endangered species are not represented in the toxicological data, the FAV could be considered reasonable. If commercially, recreationally, ecologically important, threatened or endangered species are represented in the toxicological data, the FAV may be too stringent and the following could be applied:

1. if the calculated FAV (cFAV) is less than 0.1 times the lowest GMAV, then the FAV will be 0.1 times the lowest GMAV. The 0.1 factor is chosen to prevent the calculation of an FAV too far beyond the actual GMAV dataset.

2. no adjustments to the cFAV are made if the cFAV is greater than (or equal to) 0.1 times the lowest GMAV. This applies to the data in Table 3.

3.3.2 Calculation of a Final Chronic Value (FCV)

FCV

The Final Chronic Value may be calculated in the same manner as the FAV when sufficient data are available concerning chronic toxicity to aquatic animals (Section 3.2). For an FCV, chronic toxicity endpoints are used instead of acute toxicity endpoints. Chronic toxicity endpoints are geometric means of a no observed effects concentration (NOEC) and a lowest observed effects concentration (LOEC) determined in the same

test.

ACR

Primary chronic data are scarcer then primary acute data because a chronic test lasts longer and requires more resources than an acute test. If insufficient chronic data are available to calculate an FCV as outlined above, the FCV can be calculated by dividing the FAV by the Final Acute-to-Chronic Ratio (see Appendix 4). A final acute-to-chronic ratio (ACR) can be calculated from ACRs of freshwater species from three different families, provided that at least one is a fish, one is an invertebrate and one is an acutely sensitive species. An ACR can be calculated from a primary study in which both an acute LC_{50} (a concentration lethal to 50% of the test individuals) and a chronic NOEC was determined on appropriately sensitive lifestages (USEPA 1985; USEPA 1991). An ACR is the acute LC_{50} value divided by the chronic NOEC value. Because an NOEC value is dependent on the test concentrations of a compound in a dilution series, a concentration resulting in a 25% inhibition of a chronic effect (growth, reproduction; IC_{25}) can also be used to calculate an ACR. An IC_{25} is approximately equivalent to an NOEC value (USEPA 1991).

Expert Judgement

However if the Species Mean Chronic Value (SMCV) of a commercially, recreationally or ecologically important species is lower than the calculated FCV, then that SMCV should be used as the FCV instead of the calculated FCV.

3.3.3 Calculation of a Final Plant Value (FPV)

Plants are the basis of the trophic structure of aquatic ecosystems (Wetzel 1985). Plants can use light energy to synthesize organic biomass that can either be utilized through grazing by planktivorous or omnivorous organisms. Also, plants are part of the aquatic habitat: e.g., providing cover and spawning habitat for fish, attachment for epiphytes. Effects of phytotoxic compounds could have an effect on plants and therefore on the ecosystem. Therefore, toxicity of compounds to plants is assessed by deriving a final plant value (FPV).

FPV

A plant value is the result of a short-term test conducted with an alga or a chronic test conducted with an aquatic vascular plant. The Final Plant Value should be obtained by selecting the lowest result from a test with an important aquatic plant species in which the endpoint was biologically important.

Toxicity tests for plants may be more difficult to perform than those for other aquatic organisms. A growth medium needs to be provided to promote plant growth. Growth

media contain various essential elements and often complexing agents. These compounds can affect toxicity of several water quality parameters to plants. Replacement of the growth media in most toxicity tests is rare because it would remove plants. Because of the difficulty in applying the criteria from Appendix 2 to plant studies, the final plant value may be derived with only one plant study. However, it is important to scrutinize the content of the medium for the presence of compounds that could interact with the toxicity of the test material (e.g., presence of complexing agents that reduce the toxicity of metals). If compounds affecting the toxicity of the test material are present in the medium, results from these studies should not be used for the final plant value.

Although concentrations of test material should be measured, this restriction can be lifted if the test is very short-term (e.g., tests that indicate the disruption of photosystem activity or electron transport from the water-splitting system to photosystem acceptors of algae are in the order of minutes or milliseconds).

3.4 Alberta Acute and Chronic Guidelines

Acute

The final acute value (FAV) is based on LC_{50} values which would result in severe harm to 50% of sensitive species. The FAV can therefore not be considered protective of that species. The FAV is therefore divided by 2 to protect nearly all individuals in such a genus (Delos, USEPA. n.d.: Possible Revisions to EPA's Procedure for Deriving Aquatic Life Criteria. 7p.). The Alberta acute guideline is equal to one-half the Final Acute Value (FAV, section 4.3.1). The Alberta acute guideline is therefore similar to the USEPA acute guideline or criterion maximum concentration (CMC, USEPA 1985).

Chronic

The Alberta chronic guideline is equal to the lowest of the Final Chronic Value or the Final Plant Value, unless other data show that a lower value should be used. The Alberta chronic guideline is therefore similar to the USEPA chronic guideline or criterion continuous concentration (CCC, USEPA 1985).

Expert Judgement

Pertinent information that could not be used in earlier sections might be available concerning adverse effects on aquatic organisms. The most important of these data are bioaccumulation, cumulative and delayed toxicity, reduction in survival, growth, or reproduction, attraction of biota to the compound. These factors can be used to adjust the acute and/or chronic guideline. Because these adjustments are compound-specific, no specific guidance can be provided in this protocol. Any adjustment based on expert judgement however should be well-documented and reasoned in the guideline document prepared for each compound (see also Sections 3.6 and 6.2).

3.5 Environmental Behaviour Affecting Toxicity

Water Quality Effects

When enough data are available to show that acute or chronic toxicity to two or more species is related to a water quality characteristic in a similar fashion (e.g., pH, water hardness, water temperature), the relationship should be taken into account with a covariance analysis (see Appendix 5).

Acute

For each species with acute toxicity at two or more different values of a water quality characteristic, a relationship of the acute toxicity values on the corresponding values of the water quality characteristic is determined. Appropriate transformation of the data should be used and the relationship should be evaluated for its usefulness (e.g., variability, representative range of water quality characteristic). A pooled slope and intercept for the relationships of the various species is determined. With this relationship, toxicity data are adjusted to a common value of the water quality characteristic. An FAV is calculated according to Appendix 3. If an ecologically, commercially or recreationally important species is more sensitive at a particular value of the water quality characteristic, the FAV is adjusted to provide protection for that sensitive species.

Chronic

If chronic toxicity of two or more species indicates that chronic toxicity varies with a water quality characteristic, a chronic guideline equation can be developed either as described above for the acute guideline or by adjusting the intercept of the relationship by the acute-to-chronic ratio (ACR). The latter approach assumes that the ACR is the same for all species and independent of the water quality characteristic. To use this approach, data from different species and at different values of the water quality characteristic should be available to support these underlying assumptions.

3.6 Documentation

Guideline Report

Alberta guidelines for any compound should be supported by a guideline report. The guideline document should include a condensed summary of the literature review:

- physical and chemical properties
- production and uses
- sources to the aquatic environment
- environmental concentrations in Alberta
- environmental fate and behaviour
- bioaccumulation potential
- acute toxicity to freshwater aquatic biota
- chronic toxicity to freshwater aquatic biota
- effect of a particular compound in mixtures
- genotoxicity
- organoleptic effects (if applicable)
- guidelines from other jurisdictions.

The actual derivation of an Alberta water quality guideline should be clearly outlined: the entire toxicity database should be categorized in primary, secondary and unacceptable data and provided in tables, intermediate calculation steps should be presented, and any adjustments to the procedure or guideline should be outlined and supported. Any data gaps or limits to or suggestions for applying the guideline should be clearly indicated. A suggested table of contents and a suggested table outline for the toxicity database are presented in Appendix 6.

3.7 Comparison of Alberta Protocol to Other Jurisdictions

Alberta Environmental Protection adapted the USEPA 1985 protocol for developing Alberta's aquatic life guidelines. The Alberta guidelines, when used correctly (Chapters 2 and 6), are designed to provide a reasonable and adequate level of protection with only a small possibility of overprotection or underprotection. In addition to its use by the USEPA, the same approach was also adopted by Manitoba (Williamson 1988a,b, 1990), Ministère de l'Environnement du Québec (1992), and South Africa (MacKay et al. 1995).

Comparison with CCME

As outlined earlier, existing protocols for developing guidelines for the protection of aquatic life were evaluated for use in Alberta. Appendix 1 contains a detailed comparison of the CCME and USEPA/Alberta approach. The main differences are summarized as follows:

	Alberta Approach	CCME Approach
Data Quality	Primary*	Primary*
Data Quantity	Acute guideline: eight acute values from eight different families	
	Chronic guideline: one plant species, and either eight chronic values from eight different families, or data for acute guideline with three ACR values (fish, invertebrate, sensitive species)	Chronic guideline: three values (two chronic) from three different fish species, two chronic invertebrate values from different classes, one plant species
Uncertainty Factor	Implicit (statistical approach)	Explicit
Derivation Guideline	Statistical Approach using all data & expert judgement	Lowest Value multiplied by uncertainty factor
Full Guideline	Acute and Chronic	Chronic

* see Appendix 2

The quality of the data is the same for both approaches. More information on a wider variety of species is required for an Alberta guideline compared to a CCME guideline. Alberta guidelines are calculated with a weight-of-evidence approach from all data resulting in a consistent, high level of protection. CCME guidelines are calculated by applying one uncertainty factor to the lowest effect concentration. An evaluation of available toxicity data indicated that Alberta guidelines were more protective than CCME guidelines with fewer data points and not extremely overprotective with many data points. Alberta guidelines therefore provide a more consistent high level of protection than CCME guidelines (see Appendix 1). The chronic Alberta and CCME guidelines allow assessment and prevention of unacceptable chronic toxicity in surface waters. The acute Alberta guidelines allow further assessment and prevention of unacceptable acute toxicity in surface waters (Section 2.2).

Comparison with Ontario

The water quality objective setting approach in Ontario results in a one-number (chronic) objective similar to the CCME protocol (OME 1992). The only difference is that the data requirements for setting the equivalent of full guidelines (Ontario water quality objective) are larger than in the CCME protocol: for an Ontario objective, 3 acute and 3 chronic fish studies, 2 acute and 2 chronic invertebrate studies and 1 plant study are needed. The main differences between the Alberta and Ontario approach are therefore the same as the main differences between the Alberta and CCME approach (Appendix 1).

Comparison with BC

The water quality criteria for protection of aquatic life proposed in British Columbiam follow a two-number (acute and chronic) approach (Singleton et al. 1995), as in this document. Acute guidelines are derived from acute studies and chronic guidelines are derived from chronic studies. The minimum data requirements for acute or chronic criteria are: data from 3 fish species, two invertebrate species and one plant species. These requirements are similar to Ontario's requirements. However, these data result in acute and chronic criteria in British Columbia rather than one chronic objective in Ontario. Explicit safety factors between 0.1 and 0.5 are applied to key (lowest effect) acute or chronic data in British Columbia. The main difference between Alberta and British Columbia guidelines is the derivation: Alberta uses a statistical, weight-of-evidence approach and British Columbia uses an uncertainty factor (Appendix 1).

Comparison USEPA

The classification of toxicological studies adopted in Alberta is based on the CCME protocol. Although this classification is different from that in USEPA 1985, it is consistent with the more recent test protocols for developing site-specific guidelines (USEPA 1994).

4. PROCEDURES TO DERIVE INTERIM WATER QUALITYGUIDELINES FOR PROTECTION OF AQUATIC LIFE

These procedures should be used to derive interim Alberta guidelines when insufficient information is available to derive a full Alberta guideline (Section 3.2). When the minimum data requirements for deriving interim guidelines are not met (Section 4.2), no interim Alberta guideline can be developed. Development of interim chronic guidelines is straightforward. If needed, interim acute guidelines can also be developed with this protocol. The interim Alberta guidelines should be used with the averaging period and frequency of exceedance outlined in Chapter 6.

4.1 Literature Search and Data Classification

To derive an interim guideline for a compound, a literature search is conducted similar to the search for deriving a full guideline. Each toxicological study found in the literature search is evaluated and classified according to Section 3.1 and Appendix 2. In fact, it may not be apparent whether there is sufficient information to develop a "full" or "interim" guideline until after the literature search is completed and evaluated.

4.2 Minimum Requirements for Deriving an Interim Freshwater Aquatic Life Guideline

The approach for deriving interim Alberta water quality guidelines generally follows the CCME approach for deriving interim freshwater guidelines (CCME 1991).

Minimum Data Requirement

The minimum requirements for setting an interim Alberta guideline are:

- At least two acute and/or chronic studies on two or more fish species, one of which includes a coldwater species resident in Alberta; and
- At least two acute and/or chronic studies on two or more invertebrate species, one of which includes a planktonic species resident in Alberta.

If a toxicity study indicates that a plant species is the most sensitive species in the dataset, then this study will be used in the interim guideline derivation. The minimum requirements are the same as for an interim CCME guideline.

Acceptable Data

For derivation of interim Alberta guidelines, primary and some secondary data may be used. Use of secondary data from flow-through tests is allowed for interim Alberta guidelines. In addition, results from static tests in which concentrations were measured and did not change significantly may be used for interim Alberta guidelines. The use of

secondary data for deriving interim Alberta guidelines is therefore restricted compared to the CCME protocol. During static toxicological tests, the concentration of the toxic form of a test chemical may be reduced (for instance adsorption onto particulates or test vessels). In these situations, an effect would be observed at concentrations that are actually lower than the nominal concentration initially added to the vessel. Use of higher effect concentrations may result in interim guidelines that do not provide sufficient protection. Therefore, results from static tests with nominal concentrations cannot be used in deriving an interim Alberta guideline. Unacceptable data can also not be used to derive interim guidelines.

4.3 Calculation of an Alberta Interim Chronic Freshwater Aquatic Life Guideline

The approach for deriving interim Alberta water quality guidelines generally follows the CCME approach for deriving interim freshwater guidelines (CCME 1991). The following modifications were made to the CCME approach to derive interim Alberta guidelines:

- use of secondary data for an interim Alberta guideline is restricted (see Section 4.2);
- geometric means of lowest observed effects concentration (LOEC) and no observed effects concentration (NOEC) are used instead of LOEC values;
- acute interim Alberta guidelines can be developed; and,
- expert judgement is allowed to reduce the explicit safety factors.

Method

An interim chronic guideline for freshwater aquatic life can be derived if the minimum data requirements (Section 4.2) are met. When these minimum requirements are met, interim chronic guidelines can be derived in three ways:

1. The most sensitive geometric mean of the LOEC and NOEC from a chronic study using a nonlethal endpoint is multiplied by a uncertainty factor of 0.1;

2. The most sensitive LC_{50} from an acute test or an EC_{50} lethal endpoint in a chronic test is divided by the most appropriate acute-to-chronic ratio (see Section 4.3.2);

3. In the absence of acute-to-chronic ratios, the most sensitive LC_{50} value or concentration affecting 50 percent of the test organisms (EC_{50}) is multiplied by the following uncertainty factors: 0.05 for non-persistent compounds (time in water less than 8 weeks) and 0.01 for persistent compounds (time in water 8 or more weeks).

The uncertainty factors and definition for persistence are from CCME (1991). The calculation is illustrated in Table 4 for ethylbenzene. This table represents only the most sensitive (lowest) measurement endpoints for each species. Data are from the Canadian Water Quality Guidelines Update (July 1995).

Table 4. Calculation of an Interim Chronic Alberta Guideline for Ethylbenzene in Freshwater. Data codes are: P-primary, S-secondary, M-measured concentrations, U-concentrations not measured.

		Species	Tox. endpoint	Effect Conc. (mg/L)	Data Code	Data Type	Reference
Acute	Fish	Fathead minnow	96-hr LC50	9.1	P,M	2	Geiger et al. 1990
		Goldfish	96-hr TLm	73	S,U	2	Pickering and Henderson 1966
		Bluegill sunfish	96-hr LC50	29	S,U	2	Pickering and Henderson 1966
		Guppy	96-hr LC50	9.6	S,M	1	Galassi et al. 1988
		Channel catfish	96-hr LC50	210	S,U	2	Johnson and Finley 1980
		Rainbow trout	96-hr LC50	4.2	S,M	1	Galassi et al. 1988
		Golden orfe	46-hr LC50	44	S,U	2	Juhnke and Ludemann 1978
	Invert	Daphnia	24-hr EC50	1.8	S,M	1	Vigano 1993
Chronic	Invert	Dicranophorus	6-d EC54	173	S,M	2	Erben 1978
	Plant	Selenastrum	8-d EC50	4.6	S,M	2	Herman et al 1990

Minimum data requirement is met: 2 fish species (including coldwater species resident in Alberta-rainbow trout) and 2 invertebrate species (including one planktonic species resident in Alberta-Daphnia).
Most sensitive value is 1.8 mg/L acute 24-hr EC50 value for Daphnia.
No acute-to-chronic ratios are available.
Ethylbenzene is not persistent: uncertainty factor 0.05 is applied.
Interim chronic guideline is 1.8*0.05= 0.09 mg/L

Expert Judgement

In some situations, interim guidelines may be developed differently. Expert judgement may be used for related substances in the following situation: insufficient information for a full guideline is available for substance A, a full guideline is available for substance B, and substances A and B are chemically similar and have the same toxic mechanism. In this situation, different approaches could be used and combined to derive

an interim guideline for substance A:

- the standard uncertainty factor could be reduced based on the available information on Substance A and a comparison of toxicity to substance A and B for the same species;
- the statistical approach for deriving a full guideline (Chapter 3) could be used for substance A, a comparison of the FAVs for substances A and B could be used to adjust the standard uncertainty factor.

In these cases, any adjustment based on expert judgement should be clearly described and supported with a detailed rationale.

4.4 Calculation of an Alberta Interim Acute Freshwater Aquatic Life Guideline

For deriving water quality based source standards, it may be necessary to develop an interim acute water quality guideline. Three options are outlined below:

Option 1 — Multiplying the interim chronic guideline with a measured acute-to-chronic ratio to calculate an interim FAV value, and dividing this value by 2 for an interim acute guideline.

An uncertainty factor is used in the interim chronic guideline to account for the small dataset. With this option, the same uncertainty factor applies to interim acute guidelines. The use of an acute-to-chronic ratio (as described in Section 3.3.2) for interim acute guidelines follows the protocol for full guidelines.

Option 2 — If no measured ACR values are available, a default ACR value of 10 may be used with the interim chronic guideline to calculate an interim FAV value. An ACR value of 10 represents the upper 90th percentile of ACR data (USEPA 1990). The interim acute guideline is the interim FAV value divided by 2.

Option 3 — Use available published acute guidelines from other jurisdictions as interim acute guidelines.

In some rare instances, it may be impossible to derive a full Alberta guideline even though another jurisdiction may have the equivalent of a full acute guideline. In these instances, the Alberta classification of data is likely more stringent than that used by the other jurisdiction. For interim Alberta guidelines some secondary data may be used; these data are likely used by other jurisdictions for deriving their acute guidelines.

The acute guidelines from other jurisdictions are therefore similar to interim acute guidelines in Alberta.

Example

Option 2 applies for the ethylbenzene data in Table 4: no measured ACR is available. The interim acute guideline would therefore be 0.09*10÷2= 0.45 mg/L.

If applicable, the interim acute guidelines derived by all options should be documented. When warranted, a comparison of these numbers and recommendations should also be documented. The application of these interim acute guideline numbers for deriving water quality based effluent limits will be left to the analyst deriving these effluent limits.

4.5 Documentation

Guideline Report

An interim guideline report should be prepared for each interim guideline. The content should follow the format suggested for documentation of a full guideline (Section 3.6 and Appendix 6). Any recommendation regarding use of an interim acute guideline should be documented. In addition, a specific data gaps section which clearly outlines the additional data required for the development of a full guideline should be included.

4.6 Comparison to Other Jurisdictions

CCME Manitoba, BC

The method to derive an Alberta interim chronic guidelines is similar to the CCME protocol for interim freshwater guidelines. The CCME approach is also proposed in British Columbia (Singleton et al. 1995) and used in Manitoba (Williamson 1988a). An uncertainty factor is used to derive an interim chronic guideline. This factor is used to account for the possible shortcomings of a small dataset and still provide protection to freshwater aquatic life.

The CCME protocol for interim guidelines has been slightly modified for Alberta. The major difference between the Alberta and CCME protocols is the derivation of interim acute guidelines. The CCME protocol does not result in acute guidelines. Because interim acute guidelines may be needed in some instances, three options are provided for deriving interim acute guidelines in Alberta (Section 4.4). Several other differences result in Alberta interim guidelines that are more protective than CCME interim guidelines: limited use of secondary data (Section 4.2) and use of the geometric mean of NOEC and LOEC for Alberta interim guidelines. The use of the geometric mean of NOEC and LOEC for chronic toxicity data rather than LOEC is consistent with the

derivation of a full chronic guideline in Alberta. If an interim CCME guideline is based on an LOEC value, the Alberta interim guideline will be more protective. These adjustments were made because the evaluation described in Appendix 1 indicated that the CCME guidelines developed with few data points may not be protective enough.

	Alberta Approach	CCME Approach
Data Quality	Primary and Some Secondary	Primary and Secondary
Data Quantity	2 acute/chronic studies on two or more fish species (including one coldwater species) 2 acute/chronic studies on two or more invertebrate species (including one planktonic species)	2 acute/chronic studies on two or more fish species (including one coldwater species) 2 acute/chronic studies on two or more invertebrate species (including one planktonic species)
Chronic Data Used in Derivation	geometric mean LOEC and NOEC	LOEC
Derivation	explicit uncertainty factor, expert judgement in very specific cases	explicit uncertainty factor
Interim Guideline	Chronic and Acute	Chronic

Quebec

Quebec's water quality protocol derives interim acute and chronic guidelines (Ministère de l'Environnement du Québec 1992). The minimum data requirements are smaller (one daphnid species and one of three specified fish species). Various uncertainty factors can applied depending on the available information to calculate the FAV (see Section 3.3.1). The interim acute guideline is then calculated by dividing the FAV by 2 and an interim chronic guideline is calculated by dividing the FAV by 45 (an acute-to-chronic ratio protective to 80 percent of the evaluated information). The concept of acute and chronic interim guidelines was adopted in Alberta.

Ontario

An Ontario Provincial Water Quality Guideline (OPWQG) can be developed with one toxicity study on either a fish or invertebrate species (OME 1992). The uncertainty factor to derive an OPWQG from one datapoint would be very large, but is reduced with additional data depending on the quality of the information. The uncertainty factors in OPWQG are more likely to result in significant overprotection than the interim chronic guidelines in Alberta. To provide protective and useful interim guidelines, the Ontario process was not adopted in Alberta.

5. PROCEDURES TO DERIVE SITE-SPECIFIC WATER QUALITY GUIDELINES FOR PROTECTION OF AQUATIC LIFE

Site-specific

The full guidelines derived by the procedures in Chapter 3 may be under- or overprotective because: (1) the species at a site may be more or less sensitive than those included for the provincial guideline data set, or (2) the physical and/or chemical characteristics of water at the site alters the biological availability and/or toxicity of the material. In these situations deriving a site-specific guideline may be justified. This chapter provides the approach to modify provincial guidelines for specific sites. The approach is based on science and characteristics of the site. These site-specific guidelines provide the same high level of protection to a site as the provincial guideline over the entire province.

When

An Alberta site-specific guideline can ideally only be developed if a full Alberta guideline is available. If a full Alberta guideline is not available, these procedures can be applied to USEPA acute and chronic guidelines. These procedures **cannot** be used if only an interim Alberta or CCME guideline exists.

Methods

The procedures for developing site-specific guidelines in Alberta generally follows USEPA (1994) guidelines. Two different methods are available and can be combined to develop a site-specific guideline:

1. recalculation procedure — to account for differences in resident species sensitivity to a material; and,
2. water effect ratio procedure — to account for differences in biological availability or toxicity of a material caused by physical or chemical characteristics of a site water.

The recalculation procedure generally does not involve any toxicity testing. Additional toxicity however is required when elimination of non-resident species results in a dataset that does not meet the minimum requirements for developing a full guideline. The water effect ratio (WER) procedure involves performing side-by-side tests in which the toxicity in site water and laboratory water is compared (with the same species and procedures). Carrying out studies needed to develop site-specific guidelines will generally be the responsibility of stakeholders. However, extensive consultation with Alberta Environmental Protection will be required to: determine the need for developing site-specific guidelines, ensure that proper procedures are followed, and ultimately develop a guideline that is protective of aquatic life at the site.

The following decisions must be made before either of these two methods can be initiated:

Site
- Define the site boundaries. If species sensitivity is the consideration for deriving a site-specific guideline, the site will be as large as a consistent biogeographic zone permits. If physical and chemical characteristics are the consideration for deriving a site-specific guideline, then the site would be defined on the basis of the expected changes in the material's biological availability and/or toxicity due to physical and chemical characteristics of the site water. In addition, the site must contain acceptable quality dilution water (e.g., low suspended solids) if site water is required for toxicity testing.

Bioavailability
- Determine from provincial or federal guideline documents and other sources if physical and/or chemical factors are known to affect the biological availability and/or toxicity of a material of interest.

Recalculation
- If data in the provincial or federal guideline documents and other sources indicate that the range of sensitivity of the selected resident species to the material of interest is different from that range for the species in the provincial or federal guideline document and variation in physical and/or chemical characteristics of the site water is not expected to be a factor, use the recalculation procedure (Section 5.1).

Water Effect Ratio
- If data in the provincial or federal guideline documents and other sources indicate that physical and/or chemical characteristics of the site water may affect the biological availability and/or toxicity of the material of interest, use the water effect ratio procedure (Section 5.2).

5.1 Recalculation Procedure

This procedure allows site-specific modifications to the guideline on the basis of toxicological differences between the aquatic species that occur at a site and those that were used to derive a full Alberta guideline. Reasons for these differences might be: sensitive species to a particular pollutant may not occur at a site; a species critical at a site (commercially or recreationally important, or threatened or endangered species) may be sensitive to a pollutant and require a lower guideline; or, a narrower mix of species compared to those in the provincial dataset might be present due to natural environmental conditions.

Necessary info

This procedure starts with an up-to-date dataset used to derive a provincial guideline. Additions or corrections to the provincial dataset should be based on review of the toxicological information and the classification of the study according to Section 3.1 and Appendix 2. The following information must be available:

- comprehensive information concerning what species occur at the site;
- acceptable pertinent information must be available for at least one species in each class of aquatic plants, invertebrates, amphibians and fish, and for **all** endangered or threatened species that occur at the site.

Deletion process

If any species are to be deleted from the provincial dataset, the deletion process as described in Appendix 7 must be followed.

Minimum data

When the recalculation procedure for the site-specific Final Acute Value results in a reduction in the provincial data base below the minimum data set requirement, additional resident species testing in laboratory water is necessary.

Acute

If the minimum dataset requirements are met, calculate a site-specific Final Acute Value (FAV) using all available resident species data according to the provincial protocol (Section 3.3). To derive the site-specific acute guideline, divide the site-specific Final Acute Value by 2.

Chronic

Chronic toxicity testing is likely not required for this procedure. The acute-to-chronic ratio from the full Alberta guideline can be used with the site-specific FAV. The site-specific FAV is divided by the acute-to-chronic ratio to obtain a site-specific Final Chronic Value. The site-specific chronic guideline is equal to the site-specific Final Chronic Value, unless the final plant value is lower than the Final Chronic Value (Section 3.4).

5.2 Water Effect Ratio Procedure

This procedure is based on the assumption that physical and/or chemical characteristics of water at an individual site may influence the biological availability and/or toxicity of a material. Toxicity in site water and laboratory water is determined using "standard" laboratory test species preferably a species resident at the site. The endpoint obtained using site water is divided by the endpoint using laboratory water; this quotient is the water effect ratio (WER). A site-specific guideline is equal to the provincial guideline multiplied by the WER.

Application

The WER procedure is only applicable well outside mixing zones (Figure 2). Site-specific conditions near and in a mixing zone are affected by both upstream and effluent quantity and quality and their interactions; many combinations of quantity and quality of

upstream conditions and effluent conditions are possible, which can affect the toxicity endpoints. Use of WER procedures near or in mixing zones is not recommended due to the enormous effort required to determine toxicity under a representative range of environmental conditions.

The following guidance for deriving site-specific guidelines for areas well outside mixing zones is mainly from USEPA (1994: Appendix L): method 2, deriving cccWERs (chronic criterion concentration WERs) for areas away from plumes. The WER procedure adjusts the provincial guideline based on the WER results for two species. To provide the intended high level of environmental protection, the effort to describe temporal and spatial changes in toxicity and thus variability in WER should be large.

Species

Test a minimum of two different species using laboratory dilution water and site dilution water according to toxicity test procedures resulting in primary data. The species should be in different taxonomic orders. Preferably, one species should be a vertebrate and the other species an invertebrate. The species can be either "standard" laboratory test species (e.g., fathead minnow and *Ceriodaphnia*) or species resident at the site. There are several advantages to using standard laboratory test species: test protocol for the test species is available, the sensitivity of the test species is known, and the information from tests with the laboratory water provide a direct link between the provincial guideline and the WER. Use of a "standard" laboratory test species is therefore recommended.

Species choice

One of the test species should have an effects endpoint in laboratory dilution water that is close to (but not lower than) the Alberta guideline. The available data indicate that a species less sensitive to a particular compound usually gives a smaller WER for that compound than a more sensitive species (USEPA 1994). For compounds with a lot of toxicity information on different genera, it would be possible to select a very sensitive species with an effects endpoint below the Alberta guideline. Choosing this very sensitive species is not advised, because it could result in a large WER and possibly a site-specific guideline that is underprotective. No rationale exist to support the idea that tests with the same sensitivity (effects endpoint) with different species, life stage, duration, or adverse effect will result in different WERs. Therefore WERs should not depend on the duration of the test, whether the endpoint is lethal or sublethal, or whether the species is a vertebrate or invertebrate (USEPA 1994).

The WER obtained with one species should be confirmed with at least one additional test that uses a species in a different order from the first species. The effects endpoint of this second test should be different from the first test and may be higher or lower than the Alberta guideline.

Tox. Tests

A sampling plan to collect water for toxicity tests is crucial to determining a WER for sites well outside mixing zones and has to be based on site-specific considerations. Because each site is unique, specific guidance cannot be given regarding the selection of the appropriate number and location of sampling stations for a site or the frequency of sampling. The description for this procedure will therefore be more qualitative than the procedures described for full and interim Alberta guidelines. Developing an experimental design requires a great deal of planning and understanding of the site. The experimental design and data analysis should consider the following:

- The form of the toxic compound. Is the likely toxic form dissolved rather than total? Is this fraction or the WER relatively constant or does it vary with time, location, depth? Does the WER correlate with water quality characteristics such as total suspended solids or total organic carbon across time and space?
- Extremes of physical, chemical and biological conditions within a site. The selection of number and timing of sampling events should take into account temporal (seasonal, weekly and daily) variation, spatial variation (sources of water, discharges from upstream sources, mixing patterns, current, and depth for stagnant bodies of water).
- The details of the sampling design should be formulated with an interdisciplinary team of people: e.g., with experience at the site, aquatic toxicologists, aquatic chemists, limnologists, water quality modellers, statisticians, and regulators.
- Any results of a test should be used to refine and improve subsequent sampling and toxicity testing.
- The final interpretation of the data and the derivation of a final WER from the individual WERs should be performed by a team.

The test using laboratory dilution water should be conducted so that the results would be acceptable for use in the derivation of provincial guidelines: i.e., primary data. The test using site water should be conducted using the same procedures as the tests with laboratory water. For each species, use organisms from the same population and conduct the tests at the same time and under similar environmental conditions (light, temperature, hardness, dissolved oxygen, etc.).

Water Effect Ratio

For each test with site water and laboratory water, calculate the WER as follows:

$$WaterEffectRatio = \frac{SiteWaterToxicityEndpointValue}{LaboratoryWaterToxicityEndpointValue}$$

To adjust the provincial guideline, the WER values obtained for the two species should be similar. The WERs are similar if either or both of the following are true:

- WERs obtained for the two species are within a factor of three;
- the test with the least sensitive endpoint in laboratory water results in the highest WER.

Compare the WERs for each species to determine the effect of seasonal, spatial and environmental factors on the variability of WERs. Determine through discussions within the multidisciplinary group whether the final WER should be a geometric mean of all the WER values or the lowest WER. Consider during this determination: the species present at the site and their sensitivity, the seasonal and spatial variability of WERs, the variability of WERs between species.

Final Calculation acute-chronic

The site-specific acute guideline can be calculated by multiplying the final WER by the provincial acute guideline. A site-specific FAV can be derived by multiplying the site-specific acute guideline times two. A site-specific chronic guideline can then be derived by dividing the site-specific FAV by the final acute-chronic ratio used in the provincial guideline.

6. APPLICATION OF ALBERTA GUIDELINES

Interpretation and application of guidelines is not a simple comparison between monitoring data and guidelines to determine exceedances or violations. The following sections describe some of the inherent issues that need to be considered before interpreting and applying guidelines.

6.1 Anti-degradation Clause

The guidelines developed with this protocol should not be interpreted as permitting, encouraging, or condoning degradation of present water quality in cases where present water quality is better than the guidelines. This clause is consistent with the principles for harmonization of environmental protection between the provincial and federal government and several other Agreements: e.g. International Boundary Waters Treaty Act (with the United States); Agreement on Water Quality, Schedule E to the Master Agreement on Apportionment (Prairie Provinces).

6.2 Coherence of Independently Derived Environmental Criteria

The guidelines derived with the procedures described in this protocol protect freshwater aquatic life from water exposure only. Other guidelines or approaches for other sources (food, sediment, porewater) may be needed for specific compounds to address the effects of other exposure routes on aquatic life. Different guidelines may therefore exist for the same compound. For some of these substances, it will be important to determine whether these different guidelines are coherent. Coherence of guidelines for a compound can be assessed with information on partitioning of the compound between different sources (water, food, sediment). For instance, a lipophilic (organic) substance is less likely to be present in surface water and more likely to be present in tissue residue. For this substance, food exposure may therefore affect aquatic life more than water exposure. Information on partitioning between water and tissue should be used to determine whether the water quality guideline protects consumers of aquatic life. If this is not the case, information on partitioning should be used to adjust the water quality guideline to a value coherent with the tissue residue guideline.

6.3 Indirect Effects

A specific compound may not be directly toxic at certain levels. However, its indirect effects at these levels may cause unacceptable environmental effects: e.g., severe oxygen demand as the compound is degraded or breakdown products that are more toxic than the original compound. In these instances, the guideline document for these particular compounds should clearly identify the indirect effects. In addition, specific recommendations should be made in that guideline document to consider other relevant guidelines. Expert judgement should be used and documented to set guidelines for the relevant breakdown products.

6.4 Natural Conditions

Under some natural conditions, some water quality parameters may exceed Alberta guidelines. This situation occurs most often with metals. For instance, natural erosion could result in high levels of particulate matter in water with associated metals. Also some soils can contain high levels of certain metals; surface runoff or groundwater flow from these areas could enrich receiving surface waters. These compounds could be less bioavailable and less toxic to aquatic biota. In these cases, provincial freshwater aquatic life guidelines do not apply. Site-specific guidelines can be developed as outlined in Section 5.2.

The Water Effects Ratio approach accounts specifically for physical and chemical characteristics that modify the toxicity of a compound. It involves a thorough understanding of biological and chemical characteristics of water at a site and involves comparative toxicity testing of laboratory and site water. This approach can be used to prevent development of site-specific guidelines that are more stringent than water quality under natural conditions.

6.5 Atypical Situations

This protocol has been developed on the assumptions that effects which occur on a species in the appropriate laboratory tests will generally occur on the same species in comparable field conditions. Numerous saline lakes are present in Alberta with species different from freshwater lakes. Both water and species are unlike freshwater and marine situations. Alberta guidelines could be used as an initial benchmark for comparison purposes, but alternate approaches may have to be used or developed for these atypical situations.

6.6 Mixing Zone

The use of acute and chronic guidelines in the evaluation and management of water quality is described in general terms in Chapter 2. The Water Quality Based Limits Procedures Manual (AEP 1995) describes the details that need to be considered when effluent licence limits are derived. These details include "rule of thumb" restrictions that take into account the differences in environmental conditions between different surface waters. In addition, stringent flow restrictions and high effluent loads are recommended and used in combination with the Alberta guidelines to derive limits that restrict the spatial extent of environmental effects from effluent discharges (AEP 1995). Applying Alberta guidelines with procedures to set water quality based effluent limits (AEP 1995) will prevent unacceptable environmental effects within actual mixing zones and beyond.

6.7 Low Flow Provision

Water quality in surface water depends not only on the amount of material entering surface water, but also on the quantity of surface water. For instance, river discharge varies over days, seasons, and years. These flows are important in diluting the material entering a river from point and non-point source loads. Exceedance of guidelines therefore is affected by river discharge. Critical design periods have traditionally been used not only in wasteload allocation procedures, but also in establishing instream flow needs for fish and preparing water management plans. The Water Quality Based Limits Procedures Manual recommends the use of traditional critical design periods or the use of a biologically based design flow to limit acute and chronic toxicity (AEP 1995). In addition, impacts might be restricted to a fraction of the river discharge to restrict the spatial extent of a mixing zone (AEP 1995). A comparison of surface water quality monitoring data against Alberta guidelines therefore needs to consider: the river discharge present during monitoring in light of the critical design flows, and frequency of exceedance (and possibly the averaging period) in light of biological flows.

6.8 Averaging Period

The allowance of an averaging period is based on the speed at which effects appear in different aquatic organisms exposed to different concentrations. The longer the exposure period, the more stress an individual experiences. Therefore, a threshold concentration and a threshold period will exist below which individuals will not be affected by a toxicant. However, nearly all available comparisons between tests with constant concentrations and those of the same average concentration resulting from fluctuating concentrations indicate that substantial fluctuations result in increased adverse effects.

- Acute tests generally last 48 to 96 hours. The averaging period should therefore be less than the length of the test to prevent the worst impacts of possible fluctuations. As general guidance, an averaging period ranging from 1 hour to 1 day is recommended for acute guidelines. Individual guideline documents will provide further guidance on the appropriate averaging period.

- Chronic tests generally last 7 days or longer. As general guidance, an averaging period ranging from 1 day to 30 days is recommended for chronic guidelines. Individual guideline documents will provide further guidance on the appropriate averaging period.

These averaging periods are the same as the guidance provided in the Water Quality Based Limits Procedures Manual (AEP 1995).

Considerations in choosing an appropriate averaging period are: the speed at which effects appear and the test duration for the sensitive toxicity data used in calculating either the Final Acute Value (Section 3.3.1) or the Final Chronic Value (Section 3.3.2). If the toxicity for a specific water quality parameter decreases substantially as the length of exposure increases, a longer averaging period might be acceptable. The rationale supporting the averaging period for a specific water quality parameter has to be documented in the guideline report for the specific compound.

These general averaging periods may be altered for a specific site. If the variation of a water quality parameter at a specific site is small, a longer averaging period for that site might be acceptable. Expert judgement should be used in this case.

6.9 Frequency of Exceedance

Statistically it is impossible to derive a guideline that will always be met (never exceeded). As ecological communities are naturally subjected to a series of stresses, the frequency of exceedance should be set at a level that does not significantly increase the frequency or severity of all stresses combined. The nature of ecological recovery studies does not allow a rigorous correlation between the frequency of exceeding guidelines and the resulting ecological impacts. However, conditions that slightly exceed acute and chronic guidelines are intended to result in little or no ecological effect and require little or no time for recovery.

Alberta Environmental Protection recommends that in general once in three years be

used as the frequency of exceedance (or return period) for exceeding acute and chronic guidelines. A review of field studies of disturbances causing death or displacement of organisms indicated that over 85% of the measured effects on invertebrates and fish recovered in two years (USEPA 1991). Therefore, a three-year return period is expected to provide a high degree of protection in most situations. This frequency is the same as recommended by USEPA (1991) and the Water Quality Based Limits Procedures Manual (AEP 1995). Factors to consider in modifying or applying a specific frequency of exceedance are: the nature and sensitivity of the local aquatic ecosystem and the characteristics of a specific toxicant.

6.10 Mixtures

The guidelines are derived for single compounds and generally do not take other materials (with antagonistic, additive or synergistic effects) or environmental conditions (low dissolved oxygen, temperature) into account.

Combined Effects

When an organism is exposed to two or more toxicants, the harmful effects of the mixture have in some instances been correlated by summation of their individual toxic fractions (additive). In other instances, harmful effects were greater (synergistic) or less than additive (antagonistic). Additional safety factors in deriving water quality guidelines have commonly been used to take these additive and synergistic effects into account (Alabaster et al. 1994). However, water containing several contaminants at concentrations below guidelines was found to be toxic (Wong et al. 1978).

Approach

The Alberta protocol for developing water quality guidelines does not specifically use a safety factor to account for possible additive or synergistic toxic effects in mixtures. Effluents are basically concentrated mixtures of compounds. Procedures to prevent combined toxic effects in effluents would therefore provide environmental protection. The Whole Effluent Toxicity (WET) approach is used to evaluate the combined effects of compounds in effluents.

Whole Effluent Toxicity

Whole effluent toxicity (WET) tests determine the toxicity of an effluent in a dilution series of effluent and surrogate (laboratory) freshwater. Acute and chronic toxicity endpoints are expressed as a percent effluent dilution causing either 50% mortality (or immobilization) or a no observed effects concentration (NOEC or inhibition concentration IC_{25}), respectively. Toxicity is inversely related to toxicity endpoints: the lower the effect concentration (or %dilution in WET tests) the more toxic the compound or mixture. The endpoints are therefore translated into:

Acute Toxic Units: $$TU_a = \frac{100}{LC_{50}}$$

where TU_a are acute toxic units and LC_{50} is the percent effluent dilution lethal to 50% of the organisms tested; and

Chronic Toxic Units: $$TU_c = \frac{100}{NOEC}$$

where TU_c are chronic toxic units and NOEC is the percent effluent dilution resulting in no observed effect. For example, an effluent with an acute toxicity of an LC_{50} in 10% effluent is an effluent containing 10 TU_as.

The advantage of using these toxic units is that more toxic units indicate more toxicity. However, the acute and chronic toxic units are different measurements and should not be used interchangeably.

Guideline

Toxicity endpoints in mixtures vary with test species. Therefore, the WET tests should be performed on three test species from ecologically diverse taxa. Acute and chronic guidelines are 0.3 TU_a and 1 TU_c based on the most acutely and chronically sensitive of the three species tested, respectively. The 0.3 factor for acute toxic units is used to adjust the typical LC_{50} endpoint to an LC_1 value (virtually no mortality). This factor adjusted LC_{50}s to LC_1 in 91% of 496 effluent toxicity tests (USEPA 1991). No adjustment is required for the chronic toxic units because a no observed effects concentration (NOEC or equivalent) is used to calculate chronic toxic units.

Application

The application of these guidelines for mixtures is the same as for compound-specific guidelines. Concepts such as mixing zones, averaging periods and frequency of exceedance apply to these mixtures as described above.

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8. GLOSSARY OF TERMS AND ACRONYMS

ACR	Acute-to-chronic ratio. ACR can be calculated from acute and chronic tests in the same study with the same dilution water. ACR is the acute toxicity (LC_{50}) of a sensitive lifestage divided by the no observed effects concentration (NOEC).
Acute toxicity	Toxicity that is expressed over a short time period relative to the lifespan of the organism, usually a few minutes or days. The measurement endpoint is often related to mortality (LC_{50}).
Ambient	Ambient is an adjective meaning surrounding. In water, many consider the ambient environment to be the surface waters beyond mixing zones (areas affected by point source discharges). However, the separation of the aquatic environment into mixing zones and ambient zones is not meaningful to aquatic organisms. Aquatic organisms will enter mixing zones either because they do not perceive these areas as harmful, they are unable to avoid these areas, or they may even be attracted to these zones. The term ambient is therefore not used in this document.
CCME	Canadian Council of Ministers of the Environment
Chronic toxicity	Toxicity that is expressed over a longer time period and incorporates the organism's long term response to a toxicant. The measurement endpoint is often related to effects on growth or reproduction (NOEC and LOEC).
FAV	Final acute value. Value from an intermediate step to calculate an acute guideline.
FCV	Final Chronic Value.
FPV	Final Plant Value.
GMAV	Genus mean acute value. Geometric means of all SMAVs within one genus for a specific compound.
Guidelines	A guideline is a numerical concentration or narrative statement recommended to support and maintain a designated water use. This document provides procedures to develop water quality guidelines for protection of freshwater aquatic life. Certain assumptions are made to derive Alberta guidelines. Use of any guideline requires a thorough understanding of not only these assumptions prior to application of these

guidelines but also of the information used to derive a specific guideline. A water quality guideline for protection of freshwater aquatic life is based solely on the scientific information and is analogous to an instream flow need (IFN) for water quantity (Interdepartmental IFN Task Force 1992).

IC	Inhibition concentration.
LC_{50}	The concentration causing mortality to 50 percent of the test organisms.
LOEC	Lowest observed effects concentration. This is the lowest concentration in the dilution series at which a biological response of interest was observed.
Limit	A limit is a numerical concentration, load or narrative statement that is recognized in enforceable environmental control laws by the provincial government. Further details are provided in the Water Quality Based Effluent Limits Procedure Manual (AEP 1995).
Natural	Natural water quality is the water quality without man's influence. In most cases, this is interpreted as the water quality without any point source effluents, non-point source influences, or flow alteration.
NOEC	No observed effects concentration. This is the highest concentration at which no biological response (usually adverse effects) was observed. It is always the next concentration lower than the LOEC in the dilution series.
Objectives	An objective is a numerical concentration or narrative statement that has been established to support and protect the designated uses of water at a specified site. Water quality objectives take into consideration protection of aquatic life **and** existing conditions including effluent and water licences, other uses, water management planning considerations, department objectives and public wishes. This document provides no guidance on how to develop water quality objectives.
P	Cumulative probability, statistical benchmark used to derive a Final Acute Value (FAV) or Final Chronic Value (FCV).
Primary data	Data meeting stringent requirements to evaluate data quality.
SMAV	Species mean acute value. Geometric means of all primary data from one species for a specific compound.

Site-specific guidelines	When the assumptions for deriving provincial guidelines are not applicable at specific sites, the Alberta guideline may be modified following the general procedures of the site-specific guideline protocol in this document. The Alberta guidelines can be modified when site-specific biological or chemical conditions are different from those used to derive an Alberta guideline. Applying this procedure results in a scientific site-specific guideline, which provides a high level of protection to freshwater aquatic life similar to the Alberta guideline.
Uncertainty factor	A unitless numerical value that is applied to a reference toxicological value (e.g., FCV) to account for uncertainties due to lack of species diversity to derive a guideline.
USEPA	United States Environmental Protection Agency.

Appendix 1. Comparison of the Alberta and Federal Approaches to Develop Water Quality Guidelines for the Protection of Freshwater Life

Guidelines are typically developed in two ways:

1. The lowest toxicity value is divided by an uncertainty factor (e.g., federal/CCME approach); or,

2. A statistical approach is used to derive a guideline from several toxicity values (e.g., Alberta/USEPA approach).

The uncertainty-factor approach and the statistical approach differ on several points, which complicate a simple comparison.

> The uncertainty-factor approach derives a chronic guideline (preferably) by dividing the lowest observed effects concentration (LOEC) of a chronic test by 10. An acute-to-chronic ratio (ACR) is the ratio of acute toxicity resulting in 50 percent mortality (LC_{50}) to the chronic no observed effects concentration (NOEC). The ACR value can be used with the lowest acute toxicity value to derive a chronic guideline. Alternatively, universal application factors can be used (CCME 1987).
>
> The statistical approach derives a final acute value (FAV) by interpolating or extrapolating a toxicity value corresponding to a standard cumulative probability (P) of 0.05. The acute toxicity values are toxicity values resulting in 50 percent mortality (LC_{50} values); the FAV is divided by 2 to reduce mortality to nearly all individuals in such a genus (Delos n.d.). The final chronic value (FCV) can be derived in the same manner as the FAV. The chronic toxicity values are geometric means of LOEC and NOEC; these geometric means (values lower than an LOEC) reduce the influence of the chosen test concentrations on chronic toxicity endpoints. The chronic guideline is the FCV, unless there is a meaningful chronic endpoint on a plant species that is more sensitive. Alternatively, an ACR can be used with the final acute value to derive a chronic guideline.

The first impression may be that guidelines derived with the uncertainty-factor approach are more protective than those derived with statistical approach. However, statistically derived guidelines may actually be more protective than uncertainty-factor guidelines as illustrated with actual literature data for chlordane (freshwater):

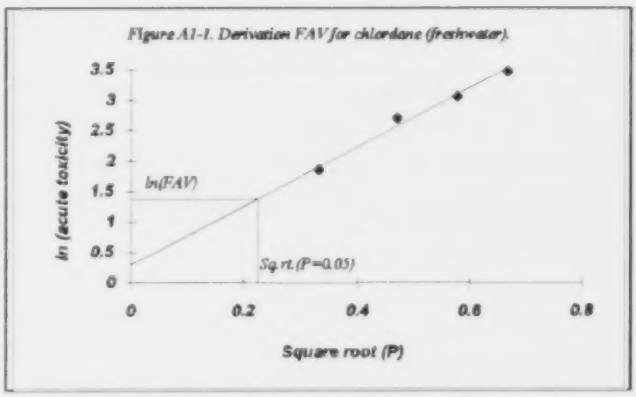
Chlordane freshwater:	acute toxicity values (LC_{50}) are: 190,59,58,44,32,21,15,6.3 mg/L data from Table 2 (Erickson and Stephan 1988)
uncertainty-factor approach:	lowest acute value= 6.3 mg/L chronic guideline = 6.3÷ACR
statistical approach:	FAV=4.0 mg/L chronic guideline = 4.0÷ACR

Consistent Level of Protection

Guidelines are meaningful if they provide a consistent high level of protection for different compounds. The statistical approach for developing guidelines was adopted in Alberta to provide a consistent level of protection to aquatic life. Compared to the uncertainty-factor approach, the statistical approach resulted in guidelines that were more protective with relatively few data points and were not unreasonably overprotective with many data points.

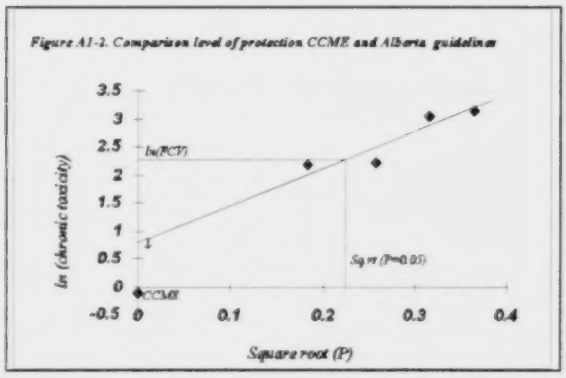
Small Data Set

Statistically derived (Alberta) chronic guidelines derived with an ACR will generally be lower than uncertainty-factor (CCME) guidelines derived with an ACR. With relatively small data sets (less than 20), an FAV will generally be lower than the lowest acute toxicity value due to extrapolation to toxicity at a cumulative probability (P) of 0.05 (Figure A1-1). The calculation of an ACR and its use in deriving a chronic guideline is the same for Alberta and CCME guidelines. An FAV lower than the lowest acute toxicity value therefore results in an Alberta guideline that is more protective than the CCME guideline.



Large Data Set

With many data points, CCME guidelines could be unrealistically overprotective. This is illustrated in Figure A1-2 with actual toxicity data for zinc in freshwater (Erickson and Stephan 1988, Table 1). A total of 29 acute toxicity data points are available for different species. For illustration purposes, these values are assumed to be chronic data points: geometric means of LOEC and NOEC for the calculation of a chronic Alberta guideline (FCV) and LOEC values for a CCME guideline. An uncertainty factor of 10 is applied to the lowest toxicity value for the CCME guideline. This value is plotted on the Y-axis of Figure A1-2 and indicated as CCME. According to the statistical approach, L represents the lowest toxicity endpoint for 100% of all species, extrapolated from the available data. In Figure A1-2, the CCME value is well below L. The CCME guideline in this case would provide an unreasonably high level of protection.



When a large number of primary toxicity values are available, a species mean acute value (SMAV) or species mean chronic value (SMCV) could occasionally be below the FAV or FCV (e.g., Figure A1-2). If these sensitive species are ecologically, commercially, recreationally important, threatened or endangered, the FAV or FCV **should** be lowered to the SMAV or SMCV of this important sensitive species. In these instances, expert judgement and stakeholder review ensure that Alberta guidelines provide an adequate, high level of protection.

The CCME approach was not adopted because it does not provide a consistent level of protection. With relatively few data points, CCME guidelines could be underprotective compared to Alberta guidelines (as illustrated in Figure A1-1). With many data points, CCME guidelines could be unrealistically overprotective (Figure A1-2).

Appendix 2. Classification of Toxicological Studies (Slightly modified from CCME 1991)

Primary Data	• Toxicity tests must employ currently acceptable laboratory practices of exposure and environmental controls. Other types of tests using more novel approaches will be evaluated on a case-by-case basis. • As a minimum requirement, variable concentrations must be measured at the beginning and end of the exposure period. Calculated concentrations or measurements taken in stock solutions are unacceptable. • Generally, static tests are unacceptable unless it can be shown that concentrations did not change (i.e., less than 10%) during the test and that adequate environmental conditions for the test species were maintained. • Preferred endpoints from a partial or full lifecycle test include a determination of effects on embryonic development, hatching, or germination success, survival of juvenile stages, growth, reproduction, and survival of adults. • Responses must be measured and should be appropriate for the life stage of the test species used. • Measurement of abiotic variables such as temperature, pH, dissolved oxygen, and water hardness should be reported so that any factors that may affect toxicity can be included in the evaluation process. The life stage of animals or plants tested should be reported. • If the tests were conducted properly, acute values reported as "greater than" values and those which are above the solubility of the test material should be used in determining the rank of the sensitive GMAVs. • While treatment replication strengthens measured toxicity endpoints and is preferred, lack of true replication is not grounds for excluding data from primary ranking.
Secondary data	• Toxicity test may employ a wider array of methodologies (e.g., measuring toxicity while test species are exposed to additional stresses such as low temperature, high salinity). • Static tests. • Preferred endpoint include those listed for primary data as well as pathological, behavioral, and physiological effects. • Calculated variable concentrations. • All relevant environmental variables should be measured and reported. The survival of controls must be measured and reported.
Unacceptable data	• Toxicity data that do not meet the criteria of primary or secondary data.

Appendix 3. Calculation of a Final Acute Value (Adopted from USEPA 1985)

A further screening of the primary data will be necessary as follows:

- If the available data indicate that one or more life stages are at least a factor or two more resistant than one or more life stages of the same species, the data for the more resistant life stages should not be used in the calculation of the species mean acute value because a species can only be considered protected from acute toxicity if all life stages are protected.
- The agreement within and between species should be considered. Acute values that appear to be questionable in comparison with other acute or chronic data for the same species and for other species in the same genus should not be used in the calculation of a species mean acute value.
- For each species for which at least one acute value is available, the species mean acute value (SMAV) should be calculated as the geometric mean of all primary data. (The geometric mean of N numbers if the Nth root of the product of the N numbers.)
- For each genus for which one or more SMAVs are available, the Genus Mean Acute Value (GMAV) should be calculated as the geometric mean of the SMAVs available for the genus.
- Order the GMAVs from high to low.
- Assign ranks (R) to the GMAVs from "1" for the lowest to "N" for the highest. If two or more GMAVs are identical, arbitrarily assign them successive ranks.
- Calculate the cumulative probability (P) for each GMAV as R/(N+1) to reduce bias (Erickson and Stephan 1988).
- Select the four GMAVs which have cumulative probabilities closest to 0.05 to reduce skewness (Erickson and Stephan 1988).
- Using the selected GMAVs and Ps, calculate:

$$S^2 = \frac{\Sigma((\ln GMAV)^2)-(\Sigma(\ln GMAV))^2/4}{\Sigma P-(\Sigma(\sqrt{P}))^2/4}$$

S is the scale parameter: i.e., the slope of the geometric mean functional relationship between lnGMAV and **p**P (Erickson and Stephan 1988).
The ln-transformation of GMAV is to reduce skewness and the **p**-transformation of P provided the best estimate corresponding to P=0.05.

$$L = (\Sigma(\ln GMAV)-S \cdot \Sigma(\sqrt{P}))/4$$

$$A = S(\sqrt{0.05}) + L$$

L is the location parameter: i.e., the intercept on the Y-axis (GMAV axis).
The slope (S) and intercept (L) values are used to calculate A: the ln-transformed toxicity value

corresponding to P=0.05.

$$FAV = e^{A}$$

FAV is A backtransformed.

- If for a commercially, recreationally or ecologically important species the geometric mean of the acute values from flow-through tests in which the concentrations of test material were measured is lower than the calculated Final Acute Value, then that geometric mean should be used as the Final Acute Value instead of the calculated Final Acute Value. Adjustments to the FAV may be made if the calculated FAV is well below the toxicity endpoint of the most sensitive genus (see Section 3.3.1).

An evaluation of this approach found that the procedure was not very sensitive to modification in the procedure, slight changes in the dataset or deviation from the assumed degree of tailing (Erickson and Stephan 1988).

Examples of FAV calculations are presented in the main text (Tables 1 and 2).

Rationale for choosing an FAV Corresponding to P=0.05

Guidelines are used in two ways: to assess water quality from monitoring data, and to set approvals limits for effluent discharges.

In water quality assessment, guidelines are used as a screening level to evaluate whether water quality is good or whether water quality is potentially not acceptable. When water quality does not meet a guideline, further evaluation is required. This evaluation results in an explanation and possibly in follow-up action. Use of underprotective guidelines would not identify all potential unacceptable conditions. When water quality guidelines are significantly overprotective, monitoring data not meeting these guidelines more than likely indicate acceptable conditions. Significantly overprotective and underprotective guidelines therefore loose their meaning and effectiveness.

Approval limits for effluent discharges are derived following the procedures in the Water Quality Based Effluent Limits Procedures Manual (AEP 1995). With these procedures, protective guidelines result in approval limits that protect freshwater aquatic life in the receiving water. Protective guidelines therefore complement the procedures to set water quality based effluent

limits (AEP 1995). This combination results in effective management of water quality and a high level of environmental protection.

Alberta guidelines are derived by interpolating or extrapolating a toxicity value corresponding to a standard cumulative probability (P). Toxicity values corresponding to different P levels would correspond to different levels of protection. The level of protection was evaluated by comparing the final acute values (FAV) derived with different P levels with the most sensitive toxicity value (see Figure A1-1). The data from Table 1 (Erickson and Stephan 1988) were used to calculate final acute values (FAVs) for different P levels. That table consists of actual toxicity data for 37 different chemicals in freshwater and saltwater. The FAVs for each chemical were calculated at cumulative probabilities of 0, 0.01, 0.05, and 0.1 and compared to the lowest acute toxicity value. For all 37 chemicals, FAVs at P levels of 0 and 0.01 consistently provided substantial overprotection against acute toxicity. The FAV at cumulative probability of 0.1 provided substantial under-production against acute toxicity. The FAV at cumulative probability of 0.05 resulted in a high level of protection without consistent substantial overprotection or under-production for the 37 chemicals. Based on this evaluation, a cumulative probability of 0.05 was chosen for derivation of Alberta guidelines. When many toxicity data points are available for a specific chemical, the FAV at cumulative probability of 0.05 may in some cases not protect every species. In these instances, the protocol has sufficient flexibility to provide additional protection. Based on expert judgement and review, the FAV for a specific chemical can be lowered to ensure that the ultimate guideline protects ecologically, recreationally and commercially important species, and threatened or endangered species.

Alberta guidelines for the protection of freshwater aquatic life derived with this protocol are therefore meaningful. Alberta guidelines provide a consistent level of protection and a high level of protection.

Appendix 4. Calculation of a Final Chronic Value (Adopted from USEPA 1985)

- Depending on the data that are available concerning chronic toxicity to aquatic animals, the Final Chronic Value may be calculated in the same manner as the Final Acute Value or by dividing the Final Acute Value by the Final Acute-to-Chronic Ratio.
- A final acute-to-chronic ratio (ACR) can be calculated from ACRs of freshwater species from three different families, provided that at least one is a fish, one is an invertebrate and one is an acutely sensitive species.
- For each chronic no observed effects concentration (NOEC) value for which at least one corresponding appropriate acute value is available, calculate an ACR. For the numerator LC_{50} use the geometric mean of the results of all primary acute tests in the same dilution water. For fish, the acute test(s) should have been conducted with sensitive lifestages. The acute test(s) should have been part of the same study as the chronic test.

$$ACR = \frac{LC_{50}}{NOEC}$$

- For each species, calculate the species mean ACR as the geometric mean of all ACRs available for that species.
- For some materials, the ACR seems to be the same for all species, but for other materials the ratio seems to increase or decrease as the Species Mean Acute Value (SMAV) increases. Thus the Final ACR can be obtained in three ways, depending on the data available:

    1. If the species mean ACR seems to increase or decrease as the SMAV increases, the Final ACR should be calculated as the geometric mean of the ACRs for species whose SMAVs are close to the Final Acute Value.
    2. If no major trend is apparent and the ACRs for a number of species are within a factor of ten, the Final ACR should be calculated as the geometric mean of all species mean ACRs available for freshwater species.
    3. If the most appropriate species mean ACRs are less than 2.0, and especially if they are less than 1.0, acclimation has probably occurred during the chronic test. Because continuous exposure and acclimation cannot be assured to provide adequate protection in field situations, the Final ACR should be assumed to be 2.

- Calculate the Final Chronic Value by dividing the Final Acute Value by the Final ACR.
- If the Species Mean Chronic Value (SMCV) of a commercially, recreationally or ecologically important species is lower than the calculated Final Chronic Value, then that SMCV should be used as the Final Chronic Value instead of the calculated Final Chronic Value.

Appendix 5. **Incorporating a Relationship between Water Quality and Toxicity into a Guideline** (Adopted from USEPA 1985).

- When the toxicity of a compound is related to a water quality parameter, this relationship should be incorporated into the guideline with a covariance analysis. Multiple regression analysis is required if two or more factors affect toxicity.
- Perform a least squares regression analysis for each species with comparable data on toxicity at two or more different values of the water quality characteristic to obtain the slope and its 95% confidence limits.
  Appropriate transformations should be applied to obain the best fit. For instance, the relationship between water hardness and acute toxicity of metals is best described by a natural logarithmic (ln-ln) relationship. The remainder of this Appendix uses ln-transformations to illustrate how a relationship is incorporated into an acute guideline.
- Decide whether the data for each species is useful considering the range and number of tested values of the water quality characteristic and the agreement between species. For example, a slope based on many data points covering only a small range of the water quality characteristics may not be useful. If useful slopes are not available for at least one fish and one invertebrate or if the slopes are too dissimilar for the various species, the relationship cannot be incorporated into a guideline. The steps outlined in Appendix 3 or 4 should be followed instead.
- With a covariance analysis determine the pooled slope from the slopes for the individual species. Determine whether the pooled slope is significant and whether the slopes for the individual species are similar.
- With the pooled slope, adjust the primary acute data to a common value of the water quality characteristic:

$$Y = lnW - V(lnX - lnZ)$$

in which Y is the ln-transformed toxicity value adjusted to a common value of the water quality characteristic (Z), W is the original acute toxicity value at the original water quality characteristic X, and V is the pooled slope. The untransformed adjusted acute toxicity value is:

$$e^{Y}$$

- Calculate the SMAVs for the untransformed toxicity values adjusted to a common value of the water quality characteristic Z.
- Proceed with the calculation steps in Appendix 3 to calculate a final acute value (FAV).
- If the SMAV at Z of an ecologically, recreationally or commercially important species is lower than the calculated FAV at Z, then that SMAV should be used as the FAV at Z

instead of the calculated FAV.

- The final acute equation is written as:

$$FAV = e^{(V[\ln(water\ quality\ characteristic)] \cdot lnA - V[lnZ])}$$

where V is the pooled acute slope, A is the FAV at the common value of the water quality characteristic Z.

Appendix 6. Suggested Content for Alberta Guideline Reports

Physical and Chemical Properties

Production and Uses

Sources to the Aquatic Environment

Environmental Fate and Behaviour

Bioaccumulation Potential (Sensitivity to birds/wildlife as consumers of aquatic life, etc)

Genotoxicity (mutagenicity, carcinogenicity, teratogenicity)

Organoleptic Effects (taste, odour, fish tainting)

Method of Analysis & Current Detection Limits

Environmental Concentrations

Acute Toxicity
Chronic Toxicity — the acute and chronic sections could be combined to discuss toxic effects on fish, invertebrates, plants, and other organisms

Effect of compound in mixtures (synergistic/additive/antagonistic effects in mixtures of compounds)

Guideline (calculations and rationale), Any Potential Limitations for Use

Other Jurisdictions/Guidelines

Data Gaps

Reference List

Appendices for primary studies used in guideline derivation (with appropriate information that classifies them as primary) and other studies (with appropriate information that classifies them as secondary or unsuitable). A proposed table for presenting the toxicological data follows on the next page.

Species & lifestage	pH	Temp (°C)	DO	Chem. cond (mg/L)	Other	Form	Effect Conc	Duration	Response	Data Codes	Data Class	Reference
Chinook salmon 1.35 g	7.6	12	near sat.	hard. 46 alk. 35		$CuSO_4$	0.025	96-hr	LC_{50}	A,F,M	1	Chapman and McCrady 1977

Data codes: A=acute C=chronic
S=Static R=Static/Renewal F=flow-through
RP/NRP=Replicated/not replicated
M=measured conc. N=nominal conc.
UK=unknown

Appendix 7. Deletion Process to Develop a Site-Specific Alberta Guideline by the Recalculation Procedure (Adopted from USEPA 1994)

Follow the steps outlined below:

1. Obtain a copy of the provincial dataset

2. Make corrections in and/or additions to the provincial dataset with only primary data, suitable for developing a full Alberta guideline

3. Group all species in the dataset taxonomically by phylum, class, order, family, genus and species

4. Circle each species that satisfies the definition of "occur at the site". The phrase occur at the site includes the species, genera, families, orders, classes and phyla that:
   are usually present at the site;
   are present at the site only seasonally due to migration;
   are present only intermittently because they periodically return to or extend their ranges into the site;
   were present at the site in the past, are not currently present at the site due to degraded conditions, and are expected to return to the site when conditions improve; and
   are present in nearby bodies of water, are not currently present at the site due to degraded conditions, and are expected to return to the site when conditions improve.

   Taxa that were once present at the site but cannot exist at the site now due to permanent physical alteration of the habitat at the site are not included as taxa that "occur at the site".

5. Circle any data for species that are surrogates of threatened or endangered species that occur at the site.

6. Use the following step-wise process to determine which of the uncircled species must be deleted and which must not be deleted (repeating steps 1 to 5 of this process for all uncircled species in the dataset):

   1. Does the genus occur at the site?
      If "No", go to step 2.
      If "Yes", are there one or more species in the genus that occur at the site but are not in the dataset?
         If "No", go to step 2.
         If "Yes", retain the uncircled species.

   2. Does the family occur at the site?
      If "No", go to step 3.

If "Yes", are there one or more genera in the family that occur at the site but are not in the dataset?

If "No", go to step 3.

If "Yes", retain the uncircled species.

3. Does the order occur at the site?

If "No", go to step 4.

If "Yes", does the dataset contain a circled species that is in the same order?

If "No", retain the uncircled species.

If "Yes", delete the uncircled species.

4. Does the class occur at the site?

If "No", go to step 5.

If "Yes", does the dataset contain a circled species that is in the same class?

If "No", retain the uncircled species.

If "Yes", delete the uncircled species.

5. Does the phylum occur at the site?

If "No", delete the uncircled species.

If "Yes", does the dataset contain a circled species that is in the same phylum?

If "No", retain the uncircled species.

If "Yes", delete the uncircled species.